

DECISION MAKING WITH MULTI-CRITERIA ASSESSMENT: HOW FIRMS TO SELECT APPROPRIATE COLLABORATION PARTNER?

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ABSTRACT

To create unique competitive advantage is becoming essential key task in industry but the limited resources constrain these activities. The collaboration is main stream in alliance strategies to gain complementary resources to create new value for customers capture. An increasing number of Taiwanese firms are strategically collaborating with Chinese partners. The appropriate partner greatly facilitates creating synergy for promoting robust business performance. But how to select suitable partner for successful value creation turn to first topic in collaboration. We propose a systematic framework for evaluating collaborative partner selection alternatives on the basis of the substantial determinants of successful collaboration. We adopt the analytical network process (ANP) technique instead of the analytical hierarchy process (AHP) and fuzzy AHP (FAHP) method due to real world consideration in interaction and feedback among each layer. This research incorporates partner necessary characteristics from prior literatures (e.g., trust, commitment, and complementarity) and new findings (value path, and intensity) in empirical cases into an ANP structure and uses expert insights as well as blurred data analysis to guide the selection processes of collaborative partners.

The Result indicate that complementary resources is the top priority for alternatives selection in electronics components distributors (ECD) field and findings contributes significant value to the design firm's collaborating management and bring high probability rate of successful collaboration.

KEYWORDS: Collaborative Partner Selection , ANP, AHP, OBOR, Successful Collaboration

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INTRODUCTION

Strategic alliances have become necessary in the electronic industry in the past few years and even been employed as a national policy such as recent One Belt One Road (OBOR) national strategy that proposed by China government for economic and political consideration.

Strategic alliance participants normally adopt several strategies activities such as cooperation, coordination, collaboration to implement mutual project or goal (Zainab Zamir, Arooj Sahar² and Fareeha Zafar, 2014). This paper focus on collaboration that a new organization is formed between two or more individual units on the basis of association, trust, and commitment and that these units consent to achieving a specific goal or completing a particular task (Bailey and Koney, 2000).

According to previous research, successful collaboration can reduce risk, accelerate time to market, lowering the cost of development, improve processes and contribute to the creation of new markets, technology, and mutual benefits as well as create value for clients (Kogut, 1988; Eisenhardt and Tabrizi, 1995; Hagedoorn, 1993;

Wheelwright and Clark, 1992). Poor selection in collaboration partner conducts significant costs and risks involved with foreign partners. Although collaboration offers attractive benefits, but also the greater investments in developing communication and coordination routines to support ongoing interactions necessary for product commercialization (Pankaj C. Patel et al., 2014).

In the electronic components distributor (ECD) field in which technological specifications are phased into electronic products such as Smartphones, Tablets, TVs, notebook, smart cars, distributors' competitive advantage such as reliability, productivity and capability are more valuable than components' cost. For a notebook manufacturer, the lowest unit cost of an outsourced TFT-LCD part is not the first priority for an appropriate supplier (A.H.I.Lee et al., 2009), whereas for product cost effectiveness, quality stability, and on-time delivery concerns (K. Shaw et al., 2012).

A key components distributor, as a part of a value chain, is dedicated to inventory management, logistical support, financial platform offering, and prompt components delivery to satisfy customers' demands. When a distributor intends to support extra value such as integrated solution to clients and expand itself business scope, collaborating with a new partner is a more efficient path for growth at the next stage. Selecting a suitable partner has become the first and most crucial step in collaboration, rather than mere investments or arms' length alliances because an appropriate partner can eventually enable expansion more efficiency, value creation and effective collaboration. Two difficulty in the field for collaboration partner selection; unclear necessary criterion and systematic evaluation tool lacking that usually cause collaboration fail. In particular, the well-informed and strategically driven selection of alliance partners is a core element in building successful alliances (Stevan R. Holmberg and Jeffrey L. Cummings. 2009).

Under the viewpoints of various scholars, most previous research has yielded results on collaborative characteristics for assessing partner selection alternatives but has failed to evaluate trust, complementarity, value path and intensity jointly. Suitable partners can effectively contribute to collaborative business development resulting in profits. Partner selection is the first priority in strategic collaboration, especially in current dynamic and complex environments (Glaister and Buckley, 1996).

When most firms are eager to gain the potential profits of collaboration, ineffective alliance partner selection is neglected but influences the effect of alliances (Hamel, 1991; Spekman and Sawhney, 1990). Astute partner selection is crucial for alliance success (Lambe, Spekman and Hunt, 2002). Partner selection should be more critical than the strongest skill and resources that a partner owns. There are several critical factors in the selection of partner such as trust, commitment, complementary resources (Shah, RH., Swaminathan V. 2008).

We adopted the Delphi method to verify impact characteristics as selection criteria according to a review of top business managers such as CEOs and vice presidents who strongly influence on enterprises decision making; we received feedback from 15 experts revealed several new crucial characteristics which are classified as follows:

- Mutual trust enables smooth collaboration at the initial stage. The motives and intention of alliance partners should be consistent with one another to avoid opportunism and reflect willingness, which relies on mutual expertise, capabilities, and judgments.
- Commitment includes responsibility, obligation and sharing necessary resources among collaborative partners, who are recognized that benefit is not a short term return but even longer than expectation in reality.
- Partners should own unique complementary resources that provide benefits.

- New value is a substantial result of collaboration and should be delivered to customers.
- Under collaborative intensity, both parties should have a strong intention to collaborate to ensure collaborative activities

In this research, three collaborative partner alternatives were measured and analyzed by examining their characteristics in Chinese ECD businesses.

However, valuable research through ANP on various partner characteristics, (e.g., research analyzing trust, commitment and complementarity as well as value path in a conceptual framework) is lacking.

Thomas L. Saaty announced the analytic hierarchy process (AHP) in 1971 in an attempt to solve the power electricity distribution problem. AHP is a method of achieving a single goal by using a multi criteria assessment, and its major purpose is to dissolve vertical hierarchy relationships and engage in quantitative assessment (Saaty, 1990a; 1990b).

AHP assumes that each layer element must be independently compared with other layer elements. Among existing AHP approaches, the extent analysis method proposed in a previous study (Chang, 1996) is a commonly applied and frequently cited approach. The AHP method can be adopted to demonstrate the hierarchy structure to review the weights of the decision-making factors evaluated by experts, and the fuzzy AHP technique can effectively clarify the vagueness of decision makers' opinions on the alternative partners weights score. On the basis of this characteristic, a previous study (Van Laarhoven and Pedrycz, 1983) first presented Fuzzy AHP in an attempt to deliver more accurate AHP assessments and the most widely used tools for multi criteria decision making (MCDM). For example, Vincent F. Yu, 2014 utilized fuzzy AHP on selection of key component vendor from three aspects; capability, productivity, and reliability which provide valued solution to real-world problem faced by a leading company specialized in the research and design of wireless networking company.

However, the structure of the AHP decision-making problem includes an unreasonable limitation in layer relationships and impact decision quality. Most decisions cannot use pure layer relationships to construct frameworks because dependence and interaction exist in the characteristics between the higher and lower layers. Therefore, a previous study (Saaty, 1996) proposed the analytical network process (ANP) in 1996, which includes the dependence and feedback concept. The difference between AHP and ANP is that AHP comprises linear hierarchies, whereas ANP represents non-linear networks and calculates weight through the super matrix or layer multiplication to determine interdependency.

This study applied the ANP technique to incorporate a collaborative partners characteristics; trust, commitment, complementarity, value path and intensity into an ANP structure and deployed decision-making experts' judgment of vague data to analyze and solve the collaborative partner selection (CPS) problem.

The remainder of this research is organized as follows. Section 2 proposes the research background and discusses related literature. Section 3 presents the methodology. Section 4 analyze CPS alternatives. Section 5 includes the discussion and conclusion. Finally, Section 6 describes the limitations and future research directions of this study.

LITERATURE REVIEW

Integrating various resources and achieving synergistic effects in alliances is the current mainstream in strategic management, but selecting appropriate collaborative partners is crucial in achieving firm objectives. Particularly, in the high-tech industrial field, most firms have faced increasing operational pressures since the environment has become

dramatically more complex, dynamic, and globally interconnected.

The complexity, expansion and diffusion of technical knowledge in various industries have extended beyond the abilities of individual firms (Powell, Koput and Smith-Doerr, 1996). Additionally, previous studies (Baldwin and Von Hippel, 2011; Von Hippel, 2005) have asserted that most firms engage in value creation through various types of multiparty collaboration to achieve mutual knowledge leverage.

Through firms' synergistic effects, focal firms' core competence can be expanded to obtain new value from collaborative partners such as those involved in e-product design and business development, producing the benefits of cost reduction and time (Haibin Yang, Yanfeng Zheng, and Xia Zhao. 2014).

Regarding the multiple characteristics for selection criteria, a previous study (Shah RH., Swaminathan V., 2008) argued that the choice of following key characteristics influences partner selection and collaborative performance: (1) trust; (2) commitment; (3) complementarity. We used value path as the fourth characteristic for the CPS features and added one more characteristic, intensity, which we derived from interviewing with 15 experts.

Trust

Trust is a key characteristic that assists in minimizing uncertainties and reducing the threat of opportunism in strategic collaboration (Anand and Khanna, 2000; Arino, De La Torre and Ring, 2001; Das and Rahman, 2001; Das and Teng, 1998).

Trust has been recognized as a social norm in governing and coordinating alliances (Anand and Khanna, 2000; Gulati. 1995; Heide and John, 1992). We operationally define trust as consisting of two dimensions: (a) benevolence; and (b) competence (Moorman and Slotegraaf, 1999; Moorman, Zaltman and Deshpande, 1992).

From a benevolence perspective, trust indicates the motives and intention of alliance partners. The action of related partners in an alliance reveals their reliance on the partners' kindness and avoids the opportunism that can occur in alliance activities.

From the perspective of competence, trust can be explained as occurring when partners exhibit traits such as integrity, credibility, reliability and expertise which reflect partners' willingness.

This study finding indentified another dimension, interaction which was operationally defined as mutual activities and frequent joint proposals as well as compromising ability, information sharing, and vision agreement.

We assert that trust is the basic characteristic in the partner selection process, especially when tangible outcomes are lacking. The initiating partner is also likely to rely on trust when outcome performance is low. Thus, when collaborative processes are unmanaged and when collaborative performance is difficult to gain benefit at a short time, the trust between partners is the first basis for partner inducement assessment and partner selection.

Commitment

Tangible input and delivery in collaboration prevent partners from behaving in a manner that is harmful to collaborative performance and increases the possibility of a successful alliance (Das and Rahman, 2001; Morgan and Hunt, 1994; Mohr and Spekman, 1994).

Failure to commit often results in alliance failure (Morgan and Hunt, 1994). Commitment can be generally defined as a willingness to engage in short-term sacrifices to realize long-term benefits (Gundlach, Achrol and Mentzer, 1995; Dwyer, Schurr PH and Oh, 1987). Commitment is also described as a pledge by a collaborative partner to undertake necessary actions to achieve the goals and objectives of collaborations; it is an essential characteristic in the partner selection process as well as long-term relationships. Thus, we operationally defined commitment in two dimensions: (a) Short-term sacrifices and (b) Long-term benefits: This study found another dimension, middle-term patience. Resource commitment often involves dedicating specific assets to collaborative projects and engaging in pledges throughout the process that continue the collaborative support. We also revealed that middle term and top management team (TMT) attitude are two additional dimensions that can be used to define commitment according to interviews with experts.

Short-term sacrifices are defined as requiring alliance partners to contribute all necessary resources without expected feedback because no collaboration can be successful at the initial stage; instead, collaboration requires partners to sacrifice their appropriated resources, particular valuable assets for collaborative activities. Middle-term patience is defined as alliance partners' efforts regarding patience; partners must remain patient to ensure that collaborative activities continue, even if no benefit is realized in the middle-term. From a long-term benefits perspective, alliance partners expect returns to exceed their expectations; partners must realize that the entire commitment process is intended to produce a long-term benefit. TMT attitude is defined as the TMT engaging in consistent recognition and maintaining collaborative activities and goals.

Complementarity

Complementarity represents the support and compatibility between partners on the effectiveness of partners loop (Hitt et al., 2004; Luo, 2002; Bucklin and Sengupta 1993; Dwyer, Schurr PH and Oh, 1987). Particularly, this study employed a variety of theoretical perspectives, including transaction cost theory (TCT) and resource-based view theory (RBVT), which has acknowledged the complementary resources, can not only reduce transition cost but also expedite collaboration between partners.

Complementarity is a critical characteristic in the partner selection process and inducement assessment because it affects the extent to which the specific abilities, critical resources, and necessary activities of organizations can be integrated successfully (Spekman and Sawhney, 1990).

When partners have complementary skills and resources, coordination between partners is facilitated (Harrison, et al., 2001; Larsson and Finkelstein, 1999). Complementary skills and resources are arguably required under all collaborative project contexts and therefore are a limited requirement for collaboration. Thus, we operationally defined complementary in two dimensions: skills and resources. Skill is an ability that is acquired through deliberate, systematic, and sustained effort that enables complex activities to be smoothly and adaptively executed. Skill can be accumulated through experience and learning. Resources are unique and cannot be replaced to maintain and improve unique company characteristics (Barney, 2001; Das and Teng, 1998). A focal firm intends to select whoever possesses a particular skills and resources; this is an essential basis for partner inducement assessment and partner selection.

We found that necessity is another expert team dimension and operationally defined partner resources as the precise resources needed for business operations.

Value Path

Axiology defines values in two dimensions, from subjective- and objective-oriented perspectives; values can be defined as usefulness or a return on goods, services, or currency that exceeds original expectations (Kumar, 2008).

Value exists because of people; they are found in two forms of human knowledge, objective and subjective knowledge. Subjective values are divided into two specific forms, perspectives and emotions. The perspective is the absolute value of, or the peoples' awareness regarding the absolute value; emotion is awareness of the relative value. Therefore, values are the relationship between subjective and objective perspectives in nature. Clearly, objective values are determined by the objective value standard, and subjective value are based on the subjective value standard. The objective value standard is the essence of subjectivity; the subjective value criterion is the subjects' desires, feelings, emotions, and interests which reflect objective values in human form.

Firms must consider and balance value creation (VC) and appropriative value (AV) governance among organizations. VC can be defined as new or innovative value that can be created by inter-organizational and transferred to end customers and AV can be defined as the resources of individual firms that can be used to increase inter-organizational value. Firms can employ organizational relationships obtain crucial resources from partners and create value (Kumar, 2008). However, in resource exchanges, partners may engage in deception, such as adverse selection and moral crisis speculation, which conduct collaboration in difficulty (Kumar, 2008; Gulati and Wang, 2003). The value of collaboration is a necessary and substantial characteristic in the partner selection process. How can value be created through internal collaborative cooperation, and why do inconsistent results occur during firm value creation and capture (J. Adegbesan JA. et al., 2010)? After new value is created by collaborative activities, the value is delivered to customers, which is a necessary final activity in collaborating. We adopted value capture as another dimension for value path characteristics.

Thus, we operationally defined value path in three dimensions: appropriative value; value creation; and value capture to form a successful "value path".

Intensity

Rehme, 1998 concluded that intensity in joint operative planning during collaboration is positively related to total logistical costs, lead times, and services in the supply chain field.

The intensity with which a partner enhances the value of the collaboration displays the intention of the partner in the selection procedure (Hitt et al., 2004; Jap, 1999; Achrol, Scheer and Stern, 1990).

The intensity of collaboration is a key characteristic in partner selection. We operationally defined intensity in three dimensions: the urgency of collaboration expresses firms' practical business situations; the requirements of partners are supported because firms are using a particular strategy or encountering a particular type of difficulty; and executive ability can be used to detect firms' intention and organizational effectiveness on the basis of expert reviews through the Delphi method.

For selecting an appropriate partner, the hierarchy structure of a problem was defined as corresponding to the CPS characteristics. Thus, each CPS characteristic was defined as a criterion and each of CPS sub characteristic was defined as a sub criterion. Table 1 defines the criteria and sub criteria used to evaluate and review all CPS characteristics.

Table 1: ANP Analysis of Collaborative Partner Evaluation and Selection

Criterion	Definition	Sub Criterion	Definition
Trust (C1)	A social norm in governing and coordinating alliances.	benevolence (BV-C11)	Motives and intention of the alliance partners will act in a manner that emerges their reliance on the partner's kindness to avoid opportunism.
		competence (CT-C12)	Integrity, credibility, reliability and expertise to reflect willingness to rely on mutual expertise, capabilities, reliability and judgments.
		Interaction (IN-C13)	Mutual activities and frequent joint proposals as well as compromising ability, information sharing, and vision agreement.
Commitment (C2)	Tangible input and delivery in collaboration.	short-term sacrifices (STS-C21)	Alliance partners to contribute all necessary resources without expected feedback.
		middle-term patience (MTP-C22)	Alliance partner's efforts regarding patience; partners must remain patient to ensure that collaborative activities continue.
		longer-term benefits (LTB-C23)	Alliance partners expect returns to exceed their expectations; partners must realize that the entire commitment process is intended to produce a long-term benefit.
		TMT attitude (TMT-C24)	Top management team (TMT) engaging in consistent recognition and maintaining collaborative activities and goals.
Complementarity (C3)	Specific abilities, critical resources and necessary activities of organizations can be integrated successfully.	skills (SK-C31)	An ability that is acquired through deliberate, systematic, and sustained effort that enables complex activities to be smoothly and adaptively executed.
		resources (RE-C32)	Unique and cannot be replaced in order to maintain and improve the company's unique characteristics.
		necessity (NE-C33)	Partner resources as the precise resources needed for business operations.
Value Path (C4)	Useful worth or return on an amount of goods, services, currency that exceeds original expectation.	appropriative value (AV-C41)	Resources of individual firms that can be used to increase inter-organizational value.
		value creation (VC-C42)	New or innovative value that can be created by inter-organizational and transferred to end customers.
		value capture (VP-C43)	New value is delivered to customers, which is a necessary final activity in collaborating.
Intensity (C5)	Strength of intention in collaboration.	urgency of collaboration (UC-C51)	Firm's practical business situations.
		support requirement (SR-C52)	Firms are using a particular strategy or encountering a particular type of difficulty.
		executive ability (EA-C53)	Detect firm's intention and organizational effectiveness.

METHODOLOGY

ANP is an advanced method for addressing the inability of decision makers to use AHP to solve the problem presented by Thomas L. Saaty in 1996. It presents an upgrade version of AHP which is a hierarchy formation as well as a linear top-down structure. ANP has a network and cluster structure and nonlinear structures that extend to the consideration of criteria in all directions (Sevcli, et al., 2012). This enables ANP to simplify the complex practical problems. This method can be used to consider the dependency and feedback relationships among characteristics and sub characteristics as well as among alternative ranking criteria and sub criteria while accounting for possible relationships among the characteristics and layers (Saaty, 2004, 1996, 1994).

In general, basic AHP procedures are defined as follows:

- The problem (goal) is placed in the top layer of the hierarchy structure, criteria, and sub criteria and alternatives are placed in descending order.
- Drive a pair wise comparison matrix in each layer, which identifies the importance and priority of any criterion with relative to other criteria by using a fundamental scale of crisp numbers ranging from 1 (equal) to 9 (absolute importance).
- Integrate all the pair wise comparison matrices to calculate the relative and whole weight of each criterion, sub criterion and alternative.

The ANP technique normally involves two methods for ranking the priority of decision-making alternatives (Gwo-Hshiung, et al., 2011). The first technique is building a super matrix, such as the W_{ij} , i th row, and j th column of the matrix, which is the principal eigenvector that represents the i th cluster influence degree on the j th cluster, the elements are compared in the super matrix. If $W_{ij}=0$, then this indicates that the i th cluster lacks a relationship between both, and it has no correlation with the j th cluster. When all the columns are conveyed to a precise unity value, then a weighted super matrix can be formed. The super matrix weights can be created and also prioritized to all options. When the weight of the super matrix and that of all the alternatives is obtained, criteria and sub criteria can eventually be determined, and the most effective alternatives can be identified. The second technique is based on the matrix's performance of a pair wise comparison of the criterion operations in each layer, including criteria, sub criteria and alternatives as well as considering the dependency and feedback for each layer by multiplying different layer priorities. This study employed the CPS approach on the basis of the second ANP technique because it is simpler and requires no complex super matrix performance (Gwo-Hshiung, et al., 2011; Sipahi and Timor, 2010).

The first step of this approach is building a hierarchy problem structure, criteria, sub criteria and alternatives on the basis of the AHP technique. The hierarchy problem structure is defined as corresponding to the selection characteristics.

The ANP method from a previous study (Yüksel, Dağdeviren, 2007) proposed strengths, weaknesses, opportunities and threats (SWOT) analyses. Our suggested necessary steps in the ANP method for selection analyses are described as follows:

- Identify necessary selection criteria, sub criteria, and possible alternative partners by using the Delphi method.
- Apply AHP to construct the hierarchy structure of the selection problem.

- Design a questionnaire on the basis of AHP structure with a crisp number scale and pair wise format.
- Apply the AHP technique, perform pair wise comparison of criteria (second layer) and form a matrix that assumes no dependency or feedback from other layers. The importance and ranking can be measured (**P1**).
- Because dependency can be assessed among CPS criteria in reality, use a scale and pair wise comparison matrices, and first create inner dependence of criteria for each criterion (**P2**).
- Use matrix multiplication to calculate the interdependent criterion priorities of CPS groups (**P3**) via by multiplying (**P1**) by (**P2**).
- Apply the AHP technique and evaluate the overall CPS sub criterion (third layer) importance ranking by using a crisp number scale and pair wise comparisons (**P4**).
- Measure the final importance rank of each sub criterion (**P5**) by multiplying (**P3**) by (**P4**).
- Apply the AHP technique and calculate the importance rank of each alternative by using a crisp number scale through pair wise comparison (**P6**).
- The overall priorities of the alternative candidates with respect to each CPS sub criterion (**P7**) can be calculated by multiplying (**P6**) by (**P5**).
- The overall priorities of the alternative candidates with respect to goal outcomes in ANP analysis can be obtained from (**P7**) calculation through **Expert Choice software**.

ANALYSIS

Empirical Case

Advanced technology-driven firms collaborate with their partners through multi alliance cooperation to eliminate the limitation of individual resources. For a qualified collaborative partner to fulfill expanding operational business requirements, alternative candidates must be evaluated systematically and prudently. In this study, a large Taiwan ECD (yearly revenue over \$3 billion, 250 employees), was assessed with a valued, potential opportunity during the next few years engage in a high-tech market such as Smartphones, Tablets, internet of thing (IOT), and smart TVs. The critical decision for this large firm is selecting an appropriative value-added collaborative partner from three alternatives:

- Candidate A is a small distributor in China. It has a strong relationship with several China brand companies. This candidate dedicates its resources to multimedia and consumer markets. The product line includes application processor (AP), graphic integrated circuit (IC), touch panels, and LED driver IC for the Smartphone, Tablet, and TV markets.
- Candidate B is also a small firm in China with a strong technical engineering team and competes with Candidate A in the China market. It has strong relationship with AP and RF IC vendors for the Smartphone, Tablet, TV, and smart car markets. Candidate B possesses a strong research & development (R&D) team and its technical solutions dominate the market with powerful support from vendors.
- Candidate C is a medium-sized firm in China and owns market shares in Smartphones and Tablets because excellent relationship with suppliers in United States and Taiwan, but insufficient ability in finance and business management.

According to the questionnaire feedback, which was obtained in survey form from an expert team that included 15 top managers (two CEOs, nine Vice presidents, one CEO special assistant, three managers) in the ECD field and received in November 2015, we collected information on five criteria and 16 sub criteria as well as construct a CPS hierarchical relationship framework. Figure 1 summarizes the results of a large Taiwan ECD problem in CPS and criterion in each layer.

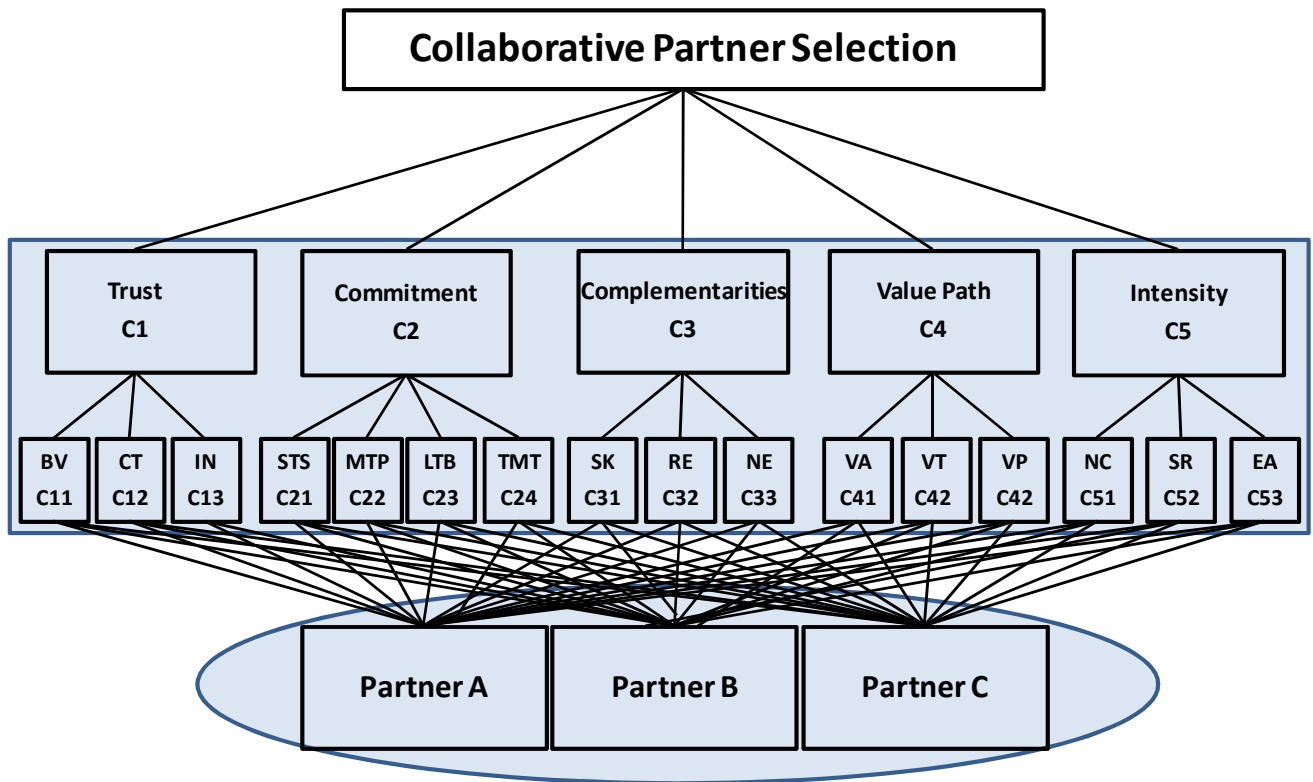


Figure 1: Hierarchy Evaluation and Selection of Collaborative Partner

After identifying the characteristics, for applying AHP and ANP analysis, the questionnaire single form was designed using pair wise comparison and scale measurement, as display in Table 2. Another in-person meeting was organized with each individual expert. After training was completed and the questionnaire instructions were provided, the forms were completed by the interviewer.

A teaching form and pair wise comparison matrix between characteristics was derived to 9 (very important) and 1(equal) for one characteristic on left side of the form and 1/9 indicates very important for the other one on the right side of the form scales were used to examine priority and interdependency of the criteria by considering the geometric mean of expert suggestions. See Table 2.

Table 2: Pair wise Scale

	Linguistic Values	Scale weight
(1)	Very Important (VI)	9
		8
(2)	Important (I)	7
		6
(3)	More Important (MI)	5
		4
(4)	Slight Important (SI)	3

Table 2: Contd.,		
		2
(5)	Equal (E)	1
		1/2
(6)	Slight Important (SI)	1/3
		1/4
(7)	More Important (MI)	1/5
		1/6
(8)	Important (I)	1/7
		1/8
(9)	Very Important (VI)	1/9

AHP Analysis

The AHP method is usually combined with other multiple attribute decision making (MADM) methods as a major tool for ranking alternatives for complex and multidimensional decision-making. These techniques consider different criteria, sub criteria, and alternatives depending on different cases to solve decision-making problems.

We followed the AHP rule and placed a goal at the top of the CPS hierarchy, criteria, and sub criteria, and the partners were placed in descending order of the hierarchical structure. At each layer, a pair wise comparison matrix can be derived. Using a pair wise comparison method, the participants could focus on each section of the problem. Additionally, two simple criteria or attributes could be considered each time. The geometric mean values of forms completed by experts were considered as a mean value of pair wise comparison matrices. Therefore, data entry was conducted using Expert Choice software for AHP analysis. This software uses the eigenvector technique. Because the eigenvector technique is highly accurate in measuring the total weights of criteria as well as calculating the index of inconsistency, the other methods were not required to apply the geometric mean.

The pair wise comparison of the CPS criteria with respect to the problem goal was applied. Table 3 (P1) displays the results of pair wise comparison regarding criteria relative priority, without considering the dependency among them at this step.

Table 3: Pair Wise Comparison of CPS Criteria Importance Degree

	Trust	Commitment	Complementarity	Value Path	Intensity	Importance Degree of CPS Criteria
Trust	1	3.302	1/6.316	1/5.646	1/3.302	0.062
Commitment		1	1/7.652	1/6.659	1/5.646	0.033
Complementarity			1	2.621	6.000	0.485
Value Path				1	4.643	0.298
Intensity					1	0.121
IR=0.1						

For the following step, the pair wise comparison for each sub criterion was implemented separately for each criterion and alternatives. Furthermore, the relative priority of each sub criterion could be determined, as displayed by the results in Table 4, including (P4).

For the next step, the overall priority of each sub criterion could be calculated by multiplying the previous result which is presented in the columns in Table 3, by the result displayed in Table 4, the results are provided in Table 5.

In the following step, this procedure was performed similarly to prioritize alternatives. The relative priority of the alternative with respect to each selection sub characteristic was calculated by considering the average of the pair wise comparison recommended by the expert team. The detailed pair wise comparisons of each alternative are displayed in Table 6 (**P6**). For the final stage, the overall priorities of each alternative were calculated using **Expert Choice** software. The results are displayed in Table 7, see table 7. We could prioritize each alternative by using the AHP technique.

Table 4: Relative Priority of Each CPS Sub Criteria

Trust	C11		C12	C13	Relative Priority
C11	1	1.0	1/7.319		0.112
C12		1	1/6.0		0.120
C13			1		0.768
IR=0.00	C11 : benevolence, C12 : competence, C13 : Interaction				
Commitment	C21	C22	C23	C24	Relative Priority
C21	1	3.634	1/2.612	1/5.646	0.112
C22		1	1/6.316	1/7.319	0.046
C23			1	1/4.642	0.222
C24				1	0.619
IR=0.09	C21 : short-term sacrifices, C22 : middle-term patience, C23 : longer-term benefits, C24 : TMT Attitude				
Complementarity	C31	C32	C33		Relative Priority
C31	1	1/7.319	1/3.634		0.075
C32		1	4.642		0.72
C33			1		0.205
IR=0.07	C31 : skills, C32 : resources, C3 : necessity				
Value Path	C41	C42	C43		Relative Priority
C41	1	1/4.642	3.302		0.202
C42		1	6.952		0.719
C43			1		0.079
IR=0.07	C41 : appropriative value, C42 : value creation, C43 : value capture				
Intensity	C51	C52	C53		Relative Priority
C51	1	1/3.915	1/7.0		0.074
C52		1	1/4.642		0.211
C53			1		0.714
IR=0.10	C51 : urgency of collaboration, C52 : support requirement, C53: executive ability				

Table 5: Overall Priorities of each CPS Sub-Characteristics by AHP Analysis

Criterion	Criterion's priority		Sub criterion's relative priority	Sub criterion's overall priority
Trust	0.062	C11	0.112	0.007
		C12	0.120	0.007
		C13	0.768	0.048
Commitment	0.033	C21	0.112	0.004
		C22	0.046	0.002
		C23	0.222	0.007
		C24	0.619	0.020
Complementarity	0.485	C31	0.075	0.036
		C32	0.72	0.349
		C33	0.205	0.099
Value Path	0.298	C41	0.202	0.060
		C42	0.719	0.214
		C43	0.079	0.024
Intensity	0.121	C51	0.074	0.009
		C52	0.211	0.026
		C53	0.714	0.086

Table 6: Overall Priority of Alternative in AHP Analysis

	C11	C12	C13	C21	C22	C23	C24	C31	C32	C33	C41	C42	C43	C51	C52	C53
Candidate A	0.333	0.163	0.140	0.297	0.163	0.196	0.196	0.263	0.190	0.249	0.135	0.196	0.163	0.528	0.297	0.157
Candidate B	0.140	0.540	0.527	0.163	0.297	0.311	0.493	0.547	0.547	0.157	0.584	0.493	0.540	0.140	0.163	0.594
Candidate C	0.528	0.297	0.333	0.540	0.540	0.493	0.311	0.190	0.263	0.594	0.281	0.311	0.297	0.333	0.540	0.249

Table 7: Final Priority of Alternative in AHP Analysis

Alternative	Overall priority of Alternatives in AHP Analysis
Candidate A	0.229
Candidate B	0.371
Candidate C	0.400

ANP Analysis

The ANP technique was applied to rank the three alternatives. This method adopts the particular results from the previous AHP analysis. In this phase, the pair wise comparison of the CPS criteria Table 3 that resulted from the AHP analysis was applied. The dependency analysis of the CPS criteria was then employed on the basis of the dominant proposal in the completed interview forms of the expert team. Reference Figure 2, it schematically presents the dependency among the partner selection characteristics. According to Figure 2, the expert team opinions were applied to analyze the interplay effects among the characteristics.

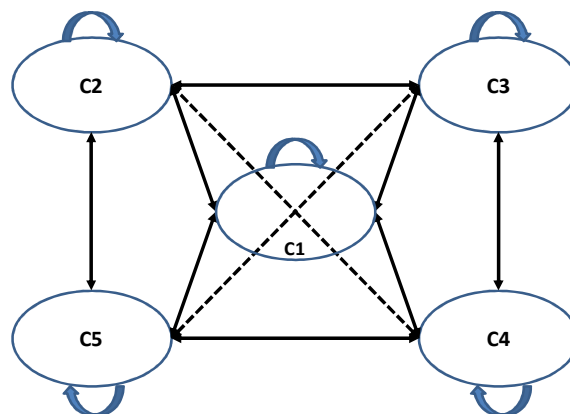


Figure 2: Interdependencies between Partner Selection Characteristics

The pair wise comparisons are detailed in Table 8. The results (**P2**) Table 8 were in this phase, and the interdependent priorities of the CPS criteria (**P3**) were calculated by multiplying the dependence matrix (**P2**) into the vector of the CPS criteria important degree (**P1**) Table 3:

Table 8: Interdependency MATRIX of the CPS Criteria Regarding other Criteria

a. consider C1					
Trust	C2	C3	C4	C5	Relative dependency
C2	1	1/3.302	1/2.885	2.289	0.129
C3		1	1/2.621	6.649	0.322
C4			1	5.313	0.487
C5				1	0.062
IR=0.06					
b. consider C2					
Commitment	C1	C3	C4	C5	Relative dependency
C1	1	1/3.302	1/5.313	2.621	0.098
C3		1	1/4.932	5.944	0.233
C4			1	7.319	0.623
C5				1	0.056
IR=0.09					
c. consider C3					
Complementarity	C1	C2	C4	C5	Relative dependency
C1	1	1.26	1/4.642	3.634	0.179
C2		1	1/5.313	2.621	0.141
C4			1	4.932	0.609
C5				1	0.071
IR=0.06					
d. consider C4					
Value Path	C1	C2	C3	C5	Relative dependency
C1	1	1/2.289	1/5.313	3.915	0.140
C2		1	1/3.634	2.621	0.203
C3			1	6.649	0.594
C5				1	0.063
IR=0.08					
e. consider C5					
Intensity	C1	C2	C3	C4	Relative dependency
C1	1	1.587	1/4.641	1/6.952	0.077
C2		1	1/3.915	1/6.316	0.065
C3			1	1/4.309	0.238
C4				1	0.620
IR=0.07					

The CPS criteria important degree (**P1**) and dependency matrix (**P2**) can be described as below:

$$P2 = \begin{bmatrix} & C1 & C2 & C3 & C4 & C5 \\ C1 & 0 & 0.098 & 0.179 & 0.140 & 0.077 \\ C2 & 0.129 & 0 & 0.141 & 0.203 & 0.065 \\ C3 & 0.323 & 0.233 & 0 & 0.594 & 0.238 \\ C4 & 0.487 & 0.623 & 0.629 & 0 & 0.620 \\ C5 & 0.062 & 0.056 & 0.071 & 0.063 & 0 \end{bmatrix} \quad P1 = \begin{bmatrix} 0.062 \\ 0.033 \\ 0.485 \\ 0.298 \\ 0.121 \end{bmatrix}$$

Used MMULT (P2, P1) mathematical equation in MS Excel tool to calculate both matrixes, result in P3 as below.

$$P3 = P2 * P1 = \begin{bmatrix} 0.141 \\ 0.145 \\ 0.234 \\ 0.431 \\ 0.059 \end{bmatrix}$$

The overall priority of each sub criterion was determined separately by multiplying (**P3**) into the sub characteristic relative importance, (**P4**) Table 4 in the AHP analysis. The results are displayed in (**P5**) Table 9.

Table 9: Overall Priorities of the CPS Sub-Criteria in ANP Analysis

Criterion	Criterion's factor		Sub criterion's relative priority	Sub criterion's overall priority
Trust	0.141	C11	0.112	0.016
		C12	0.120	0.017
		C13	0.768	0.108
Commitment	0.145	C21	0.112	0.016
		C22	0.046	0.007
		C23	0.222	0.032
		C24	0.619	0.090
Complementarity	0.234	C31	0.075	0.018
		C32	0.72	0.168
		C33	0.205	0.048
Value Path	0.431	C41	0.202	0.087
		C42	0.719	0.310
		C43	0.079	0.034
Intensity	0.059	C51	0.074	0.004
		C52	0.211	0.012
		C53	0.714	0.042

The overall priority of the alternative candidates with respect to each CPS sub criterion (**P7**) Table 10 was obtained by considering the average of the experts' pair wise comparison through by multiplying (**P5**) Table 9 into the overall priority of the alternative candidate in the AHP analysis (**P6**) Table 6.

Table 10: Overall Priority of Alternative in ANP Analysis

	C11	C12	C13	C21	C22	C23	C24	C31	C32	C33	C41	C42	C43	C51	C52	C53
Candidate A	0.005	0.003	0.015	0.005	0.001	0.006	0.018	0.005	0.032	0.012	0.012	0.061	0.006	0.002	0.004	0.007
Candidate B	0.002	0.009	0.057	0.003	0.002	0.010	0.044	0.010	0.092	0.008	0.024	0.153	0.018	0.001	0.002	0.025
Candidate C	0.008	0.005	0.036	0.009	0.004	0.016	0.028	0.003	0.044	0.028	0.051	0.096	0.010	0.001	0.007	0.010

The overall priority of the alternative candidates with respect to goal outcomes is proved in Table 11 and in the ANP analysis through Expert Choice software.

Table 11: Final Priority of Alternative in ANP Analysis

Alternative	Overall priority of alternatives in ANP analysis
Candidate A	0.189
Candidate B	0.504
Candidate C	0.308

Therefore, the ranking of the three selection alternatives for CPS in the ECD field was determined by considering the interdependency between selection criteria.

DISCUSSION AND CONCLUSIONS

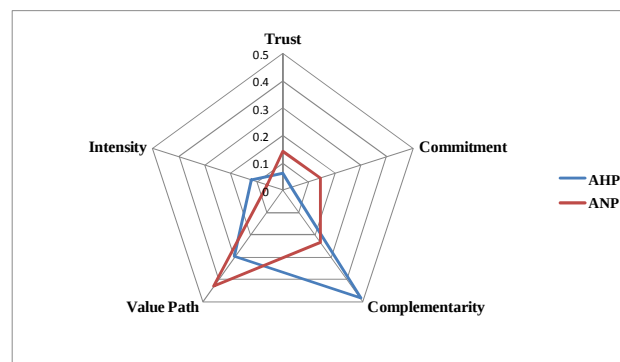
According to the result from ANP regarding CPS, we considered the dependence and feedback among criteria, sub criteria, and alternatives and repaired the possible interdependence and feedback in the real world. The overall calculated priority for the ANP technique is different from that of AHP. The ranking result attained from comparing AHP and ANP is displayer in Table 12.

Table 12: Comparison of ANP and AHP

Alternative	Overall priority		Ranking result	
	ANP	AHP	ANP	AHP
Candidate A	0.189	0.229	3	3
Candidate B	0.504	0.371	1	2
Candidate C	0.308	0.4	2	1

Table 12 indicates that the final ranking of alternative candidates totally differed. The top-down sequence ranking in AHP is C-B-A (Candidate C is weighted most heavily, indicating that it is the most suitable candidate) but B-C-A in ANP (Candidate B is the most suitable choice). Obviously, dependence caused a remarkably different result in CPS. An error in partner selection can result in major investment losses regarding not only finance but also unique and essential enterprise resources.

With more detailed difference between two analytical methods from the criteria perspective, we could use radar graphic (see figure3) for easier judgment in individual criteria priority. The AHP regards complementarity as first priority and then value path and ANP conversely. The ANP considers with interdependency and feedback which value path is first criteria and then complementarity. The ANP is more consistency with real world since the main purpose of collaboration is value creation and it can be captured by customers. Firms ought to put value path in the first mirror in CPS.

**Figure 3: Difference among AHP and ANP in CPS Criteria**

This research contributes to a greater understanding of collaborative partner selection according to multiple criteria (e.g., trust, commitment, complementarity, value path and intensity).

An appropriate partner increases the probability of successful collaboration as well as avoids unnecessary transaction cost and the wasting of additional resources.

This empirical case study, which examines problems for assessment, evaluation, and analysis of decision-making for CPS in the ECD field, inspires essential insights in MCDM.

Regarding the synergistic supply chain and value chain ecosystem, we contribute the following items to industry and academia:

- The empirical research contributes a guideline on appropriate collaboration partner selection.
- This research clarifies the previous uncertainty on collaborative partner selection criterion and process in industry.
- The characteristics evaluation is based on the case study firms' examination and partners' perspectives according

to five criteria and 16 sub criteria which 2 new criteria from our new findings. The comprehensive criterion characteristics focus on (i) trust, (ii) commitment, (iii) complementarity and two new findings: (iv) value path, and (v) intensity.

- This research specifies that differences between the AHP and ANP techniques by comparing practical cases from China and Taiwan firms and evidence in the result that validates ANP is a more accurate method in MCDM.
- We adopt value path as one of the key criteria that have been neglected by past studies; this criteria can most affects guideline selection in ANP analysis.

Because ECDs are positioned at the low level of the value chain, they are forced to create new and innovative value for additional benefit through collaboration with appropriate partners. Before firms implement strategic collaboration, partner selection is the first priority.

The research offers important insights for managers of ECD to understand better how to select appropriate partners. Managers should proactively design their collaboration partner selection and consider complete characteristics with ANP.

LIMITATIONS AND FUTURE DIRECTIONS

This paper contribute substantially to the understanding of partner selection, which incorporates the collaboration selection process and it is most other frameworks in the literature neglect. This research has two limitations, which motivate us to engage in future research. The first limitation is that only five criteria within this CPS were used. We expect that future studies can identify more criteria to enrich the theoretical context of CPS. The responses from these three alternatives can then be assessed according to correspondence and accuracy. A second limitation is that this study examines the ECD industry that limits its scope. The future study we proposed should apply this methodology to other industries.

In summary, partner selection is the first stage of successful collaboration. Previous studies in this area have been limited because they have ignored theoretical characteristics as a crucial factor in understanding why and how managers select partners with specific characteristics. The present study is a first step in filling this void. We hope that is will guide further study in this crucial area.

CONFLICTS OF INTEREST

The authors declare no conflicts of interests regarding the publication of this paper.

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